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# Software For Accelerators

Paul Lebrun  
Accelerator Activity Coordination Meeting  
August, 2004

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# Topics...

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- SDA: Making Accelerator data available to physicists, engineers and managers.. (S. Panacek, K. Genser, P. Lebrun)
  - Infrastructure
  - Analysis tools.
  - Beam Physics Analysis
- Magnet Database Project (D. Box, M. Fischler)
- Tevatron Instrumentation Projects ( excluding BPM)
  - Real-time longitudinal emittance calculation for SBD ( A. Para)
  - Tevatron Tune Fitter - 1.7 GHz, 21.4 MHz (P. Lebrun)
- Input to VAX-VMS migration project and improvement to Control System (R. Rechenmaker, S. Panacek, P. Lebrun)
- Outlook : what's next ?

# SDA : Introduction

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SDA is a system for acquiring, archiving and analyzing data from stores.

- *Slides borrowed from talk presented at ICAP04, summarized.*
- Objectives & Scope
- Data Acquisition and Archiving Aspect. (Skip!..)
- Analysis (SDA = Shot Data Analysis, for us)
  - Tools & computing aspects
  - Output
    - Web based
    - Summary table
    - Detailed information
    - Application Interfaces
- Analysis results:
  - Tevatron complex performance assessment via SDA

# The Team

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- SDA Group in Integration Department
  - K. Gounder, E. McCrory, V. Papadimitriou, J. Slaughter
  - Coordination, monitoring, analysis
- Controls Department
  - T. Bolshakov, M. McCusker, K. Cahill, B. Hendricks, J. Patrick and others
  - Infrastructure and applications
- Computing Division
  - K. Genser, P. Lebrun, S. Panacek
  - Analysis and applications

A collaboration between A/D Controls, Computing Division, A/D physicist, CDF/DO. The coordination is the responsibility of the Accelerator Integration Department

# Scope of SDA : "Store" Performance analysis

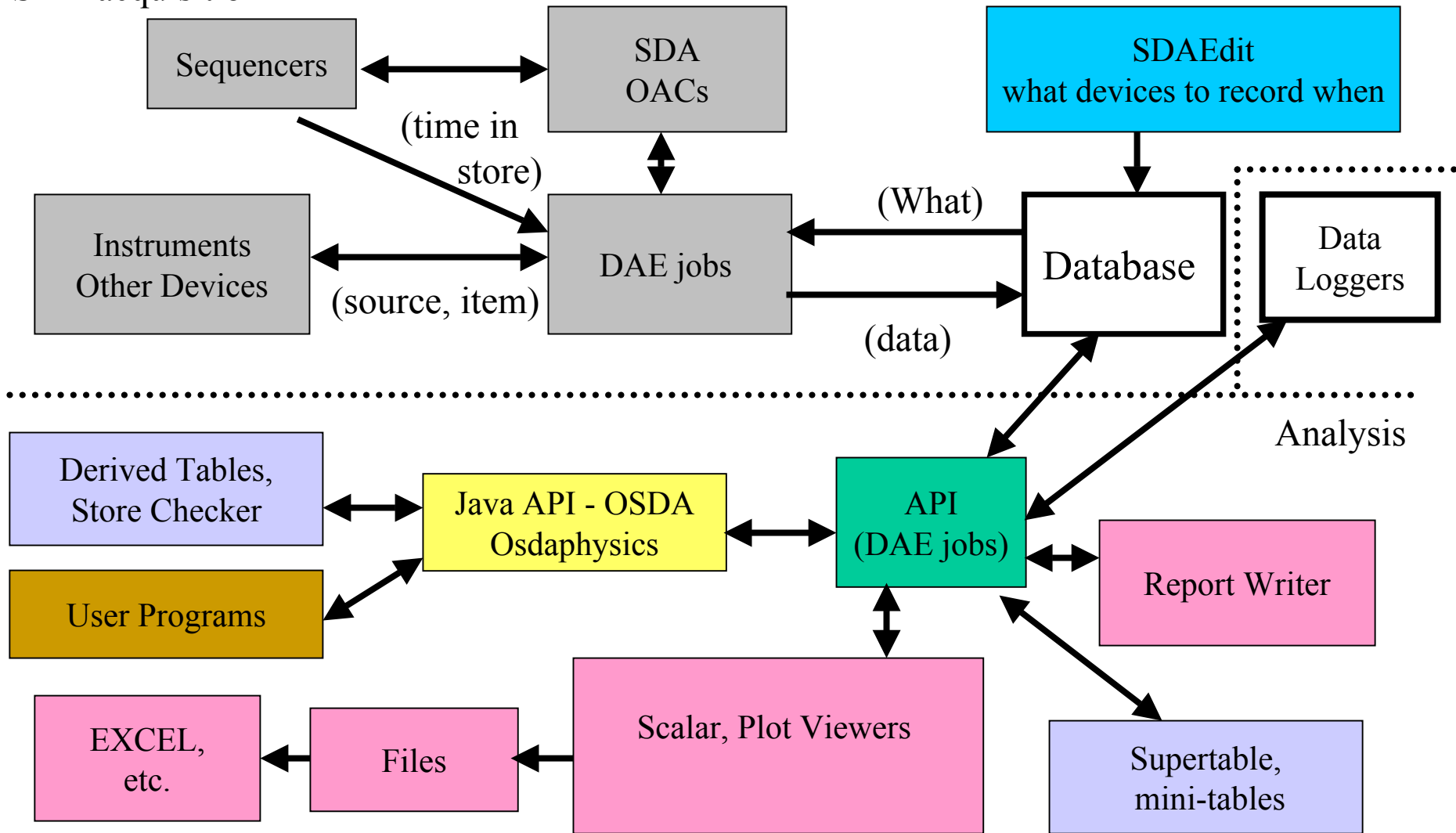
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Ultimate Goal: More integrated luminosity usable by the experiments

- Allows correlation of information from multiple sources at specific times during the stores
- Information for day to day monitoring of stores
- Specialized studies
  - Long term trends
  - Investigate correlations
    - Luminosity vs. emittances, number of protons and anti-protons
  - Accelerator physics questions
    - Pbar Burn rate / total loss rate during HEP
    - Orbit changes
    - ??
- The Tevatron complex includes the proton and antiproton sources, the Main Injector and the Recycler.

# Data Acquisition and Analysis Tools Diagram

SDA acquisition



## SDA - Computing Aspects

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- Programming language : Java! - both for data acquisition and analysis.
- Extensive use of high-level communication protocols, such as R.M.I.
- Multi-tier architecture: use of "servlets" applications to extract data
- Simple and straightforward use of relational database (SYBASE and MSQL) to hold the data.
- We rely on the Web for distribution of summary plots and tables (Excel or HTML), and API code distributions
- Coherent data access for both "sequenced" (triggered) and "periodic" (1 Hz -> 5 min) data.

# Analysis Tools

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- Data Browser on the web or standalone Java (SDAViewer)
- Report Writer for quick studies
- Tables built automatically every store
  - Supertable and EXCEL package
  - Derived tables and associated plotting tools
  - Short summary tables
  - Tables use corrected values
- Shots scrapbook
- OSDA (Offline Shot Data Analysis) - Suite of Java classes for user programs to directly access the data, apply corrections and calculate generally useful quantities like lifetimes (mostly S. Panacek )
- OSDAPhysics : Suite of Java class for beam physics studies (K. Genser, P. Lebrun,.... )



# SDA Data

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- Intensities
- Beam sigmas and transverse emittances
- Bunch lengths and longitudinal emittances
- BPM orbits
- Luminosities, losses, beam positions from CDF/DO
- Magnet settings, readbacks
- Misc. devices like RF control signals
- Fast Time plots of intensity devices and control settings
- Tevatron tunes
- Beams Division Documents 691, 692, 703, 705

# Supertable

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- One line per store
- Built automatically every store
- 130+ quantities of general interest
  - Dates, time on helix, length of store
  - How store ended
  - Luminosities, intensities at collision
  - Efficiencies at each stage from p, pbar sources to HEP
  - Emittances at each stage
  - Peak, average losses
  - Lifetimes, etc.
  - Averages over all bunches, for each quantity
- Web Accessible - HTML, EXCEL
  - analysis with plots, tables also on Web

# Edited Excerpt from Super Table

0 Store #	1 Date started shot set up	7 store length (hours)	8 how store ended	10 start stack	11 unstacking fraction	12 amount unstacked
3228	2/12/2004	0.22	Not Completed	135.19	0.88	119.2
3226	2/10/2004	33.31	Normal	160.39	0.86	138.6
3224	2/8/2004	36.92	Normal	149.39	0.87	129.6
3222	2/7/2004	40.18	Normal	177.19	0.81	144.2
3219	2/5/2004	31.09	Normal	173.79	0.85	147.6
3217	2/3/2004	27.98	Normal	204.19	0.8	163.4
3214	2/2/2004	33.89	Normal	208.19	0.75	156.4
3212	1/31/2004	31.37	Normal	175.19	0.78	136
3210	1/30/2004	14.65	Normal	189.39	0.62	118
3206	1/29/2004	15.1	TevQuench	80.59	0.94	75.4
3197	1/27/2004	32.38	Normal	120.39	0.9	108.6
3195	1/26/2004	2.68	Abort	145.39	0.91	131.6
3191	1/25/2004	17.9	Abort	103.79	0.93	96.2
3189	1/23/2004	35.76	Normal	142.39	0.88	125.2
3185	1/22/2004	26.41	Normal	133.19	0.9	120.4
3183	1/21/2004	23.59	Normal	120.39	0.85	102.6
3179	1/19/2004	27.76	Normal	163.19	0.86	140.4
3177	1/17/2004	22.27	Normal	172.39	0.81	140
3175	1/16/2004	25.07	Normal	176.39	0.7	123.6
3172	1/15/2004	21.48	Normal	159.99	0.51	81.2

# Derived Tables- Bunch by Bunch Information

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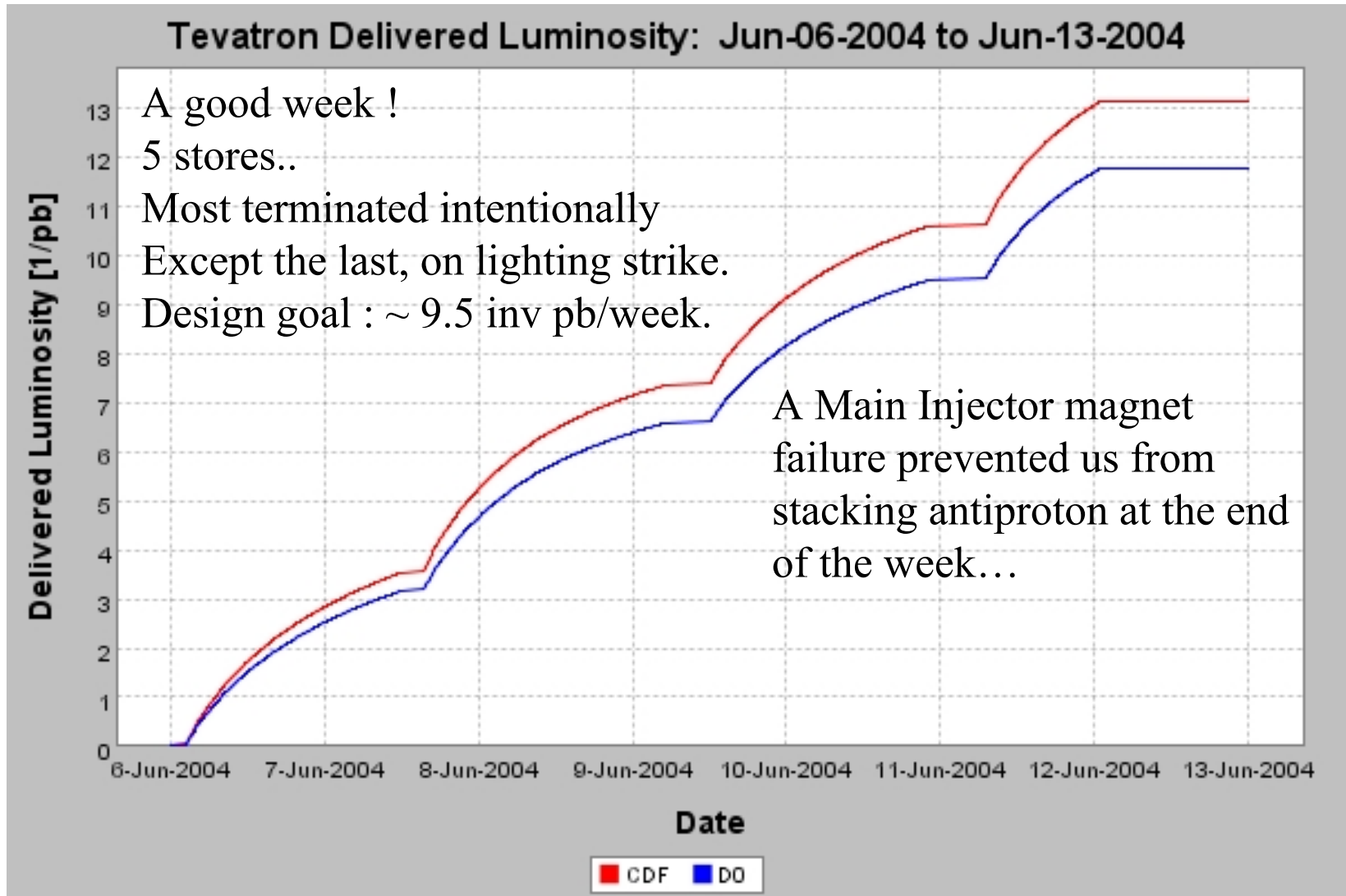
- Table per store - built automatically
  - All 6 emittances
  - Intensities
- Average and bunch by bunch information
- Use best algorithms to get physics quantities
  - Not always available directly from front-end.
- Interactive plotting interface

# Store Checker

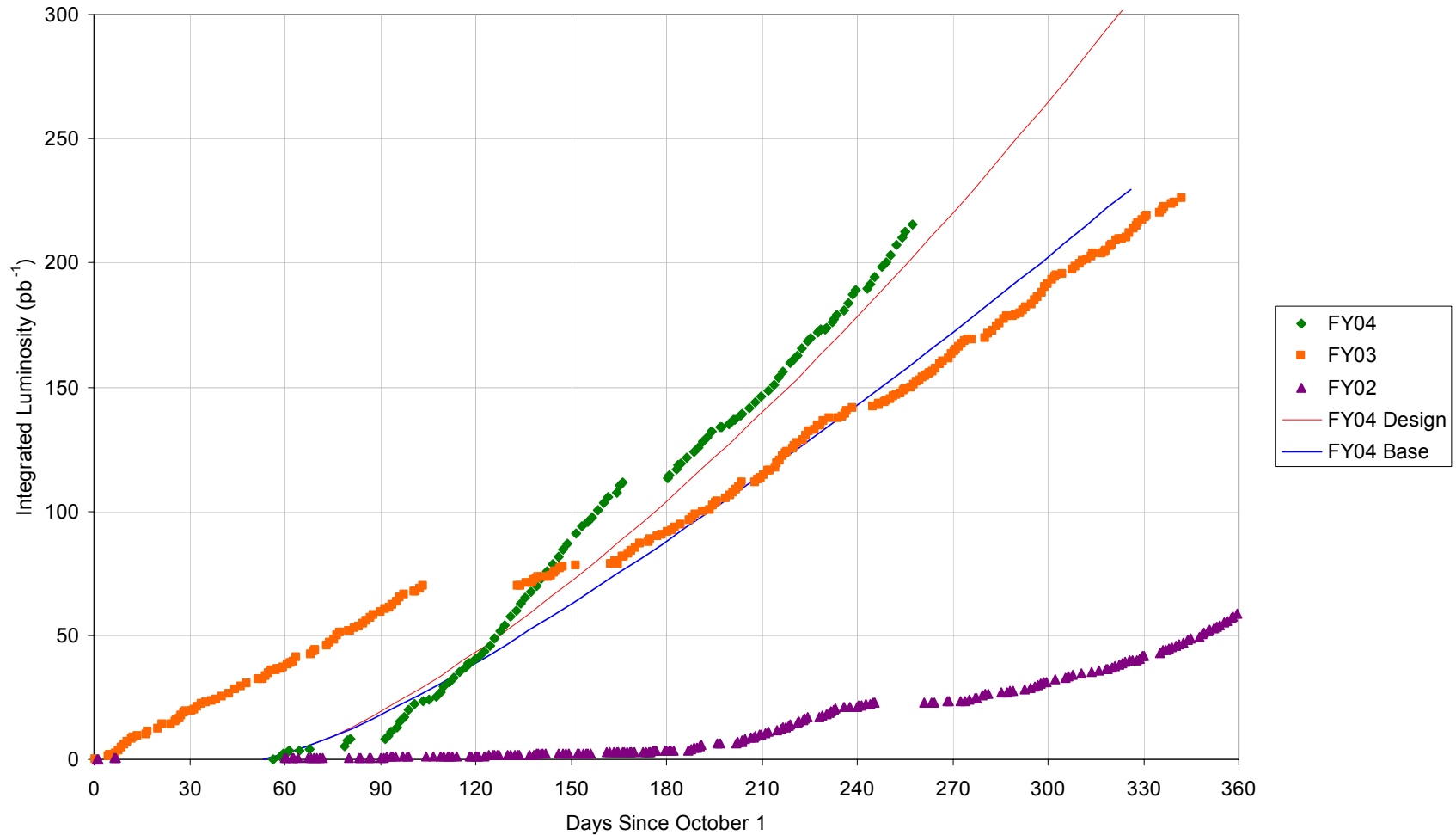
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- Purpose
  - Monitor instrumentation and DAQ
  - Monitor accelerator performance - soon
- Checks SDA data for specified cases/sets
  - $\text{Min} < \text{device value} < \text{max}$
  - $\text{Min} < (\text{difference in time of 2 devices}) < \text{max}$
  - $\text{Min} < (\text{difference in value of 2 devices}) < \text{max}$
- Jobs run automatically every store
- "Standard" and "private" lists
- Results on WWW for "standard" list
- Lists on WWW
- Used to give email notification of initial luminosities

# Integrated Luminosity Table and Plot



# Fiscal Year Integrated Luminosity



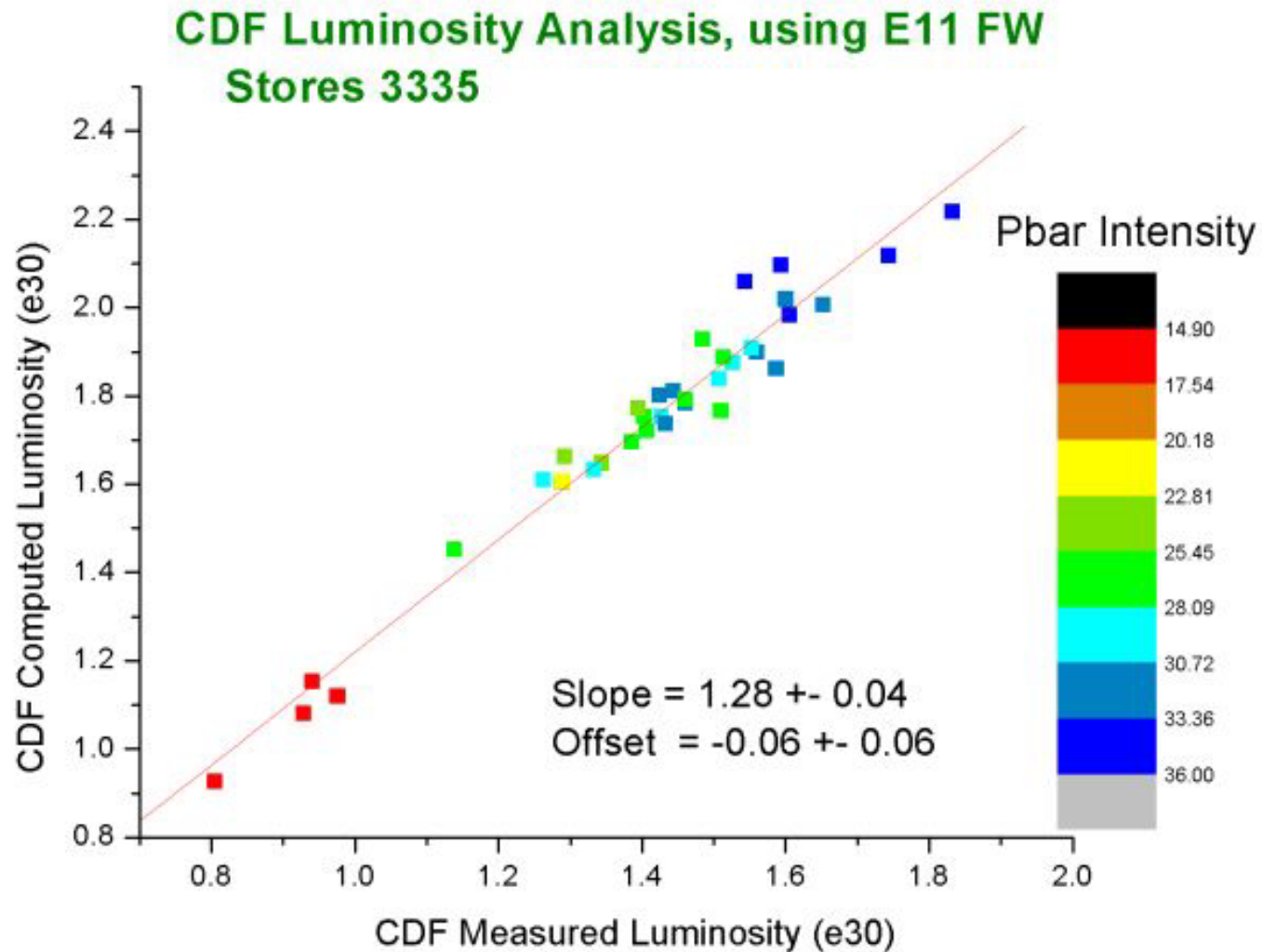
# Examples of Detailed Analysis

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- These two last plots described our overall performance. Improving them requires meticulous analysis work based on many data sources.. Thus:
  - Is data acquisition reliable?
  - Is the instrumentation adequate?
    - Relative calibrations between devices and same devices in different machines
    - Systematic and statistical errors
- Let us go through a few examples of detailed analysis based on SDA tools and data sets:
  - Bunch by bunch Luminosity expectation (Skip)
  - Tevatron Transverse Emittances. (K. Genser)



# Example of Analyses

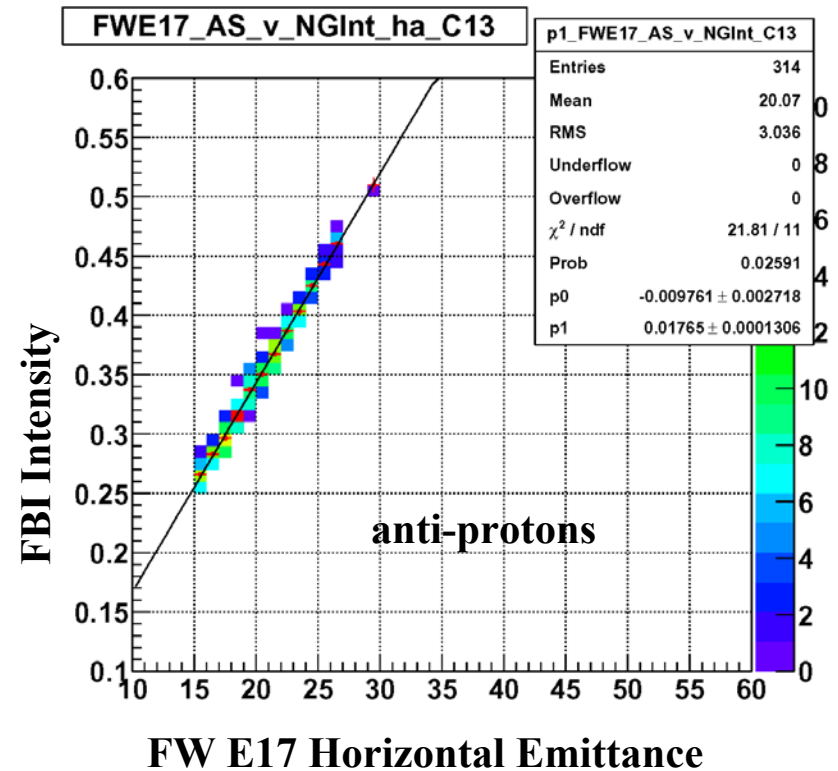
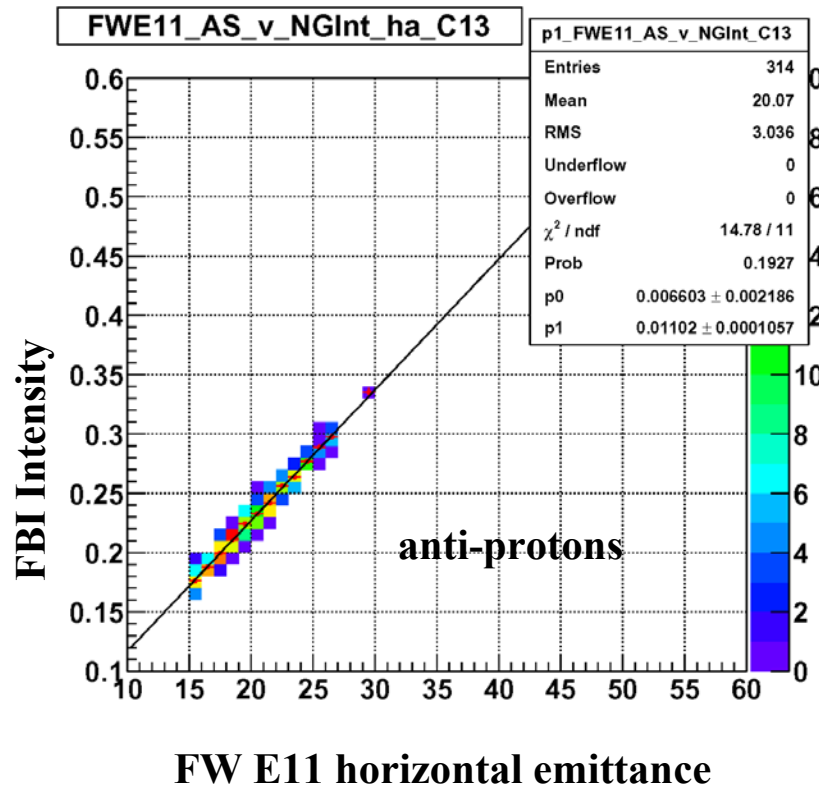


# Understanding Tevatron Flying Wires and SyncLite

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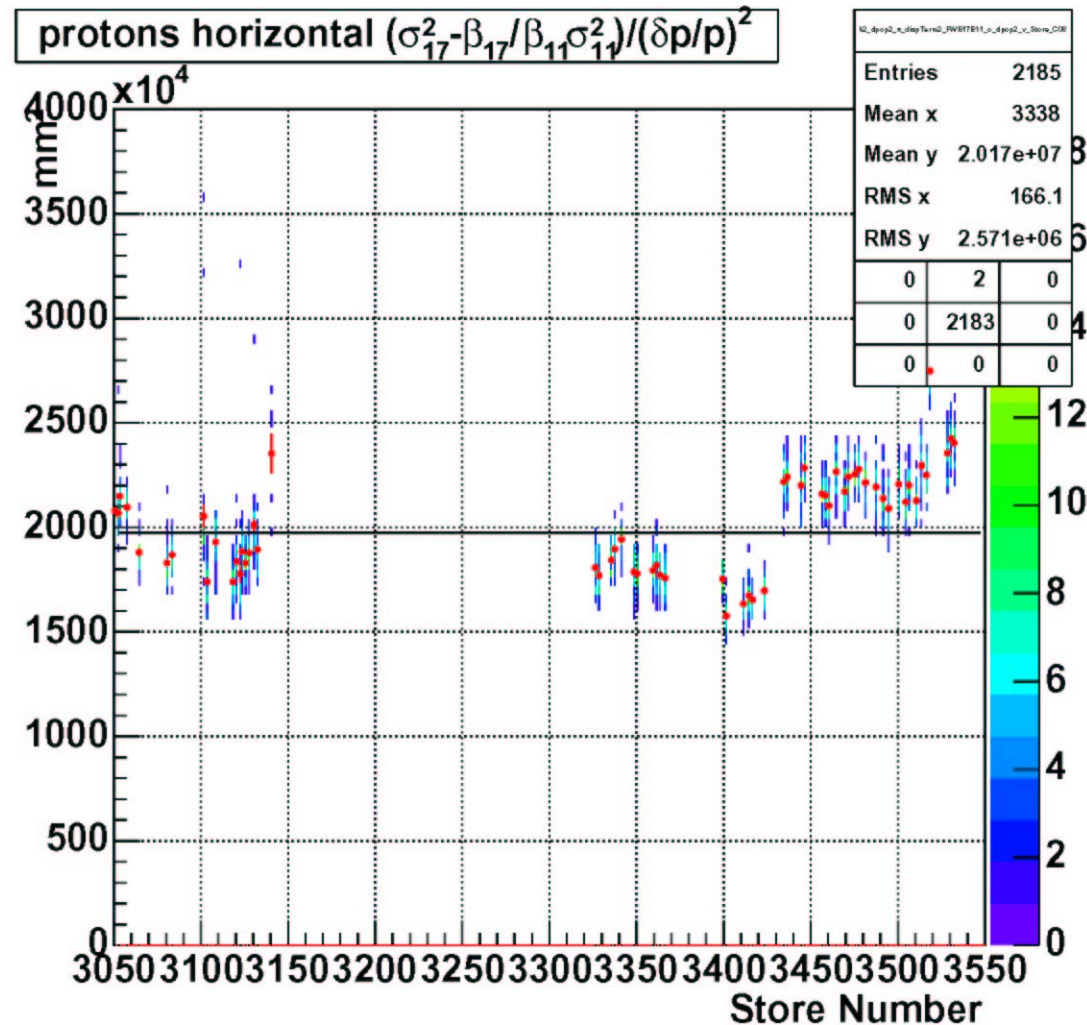
- Compare area of FW profile to FBI intensity
  - Very linear
  - Qualitative agreement given differences in gain and acceptance of the paddles
- Compare horizontal emittance as measured at E11 with E17 emittance, using SBD for  $dp/p$ 
  - Anti-protons - ratio has slope of .97 and intercept of 1.25 - after fixing saturation
  - Protons - poor agreement, slope .41, intercept 14.5
- Compare area of SyncLite profile with FBI intensity
  - Better for anti-protons than for protons
- Compare flying wire emittances with SyncLite emittances
- Very sensitive to lattice parameters and  $dp/p$
- Store to store variations
- ....

# Compare FW Emittance with FBI Intensity

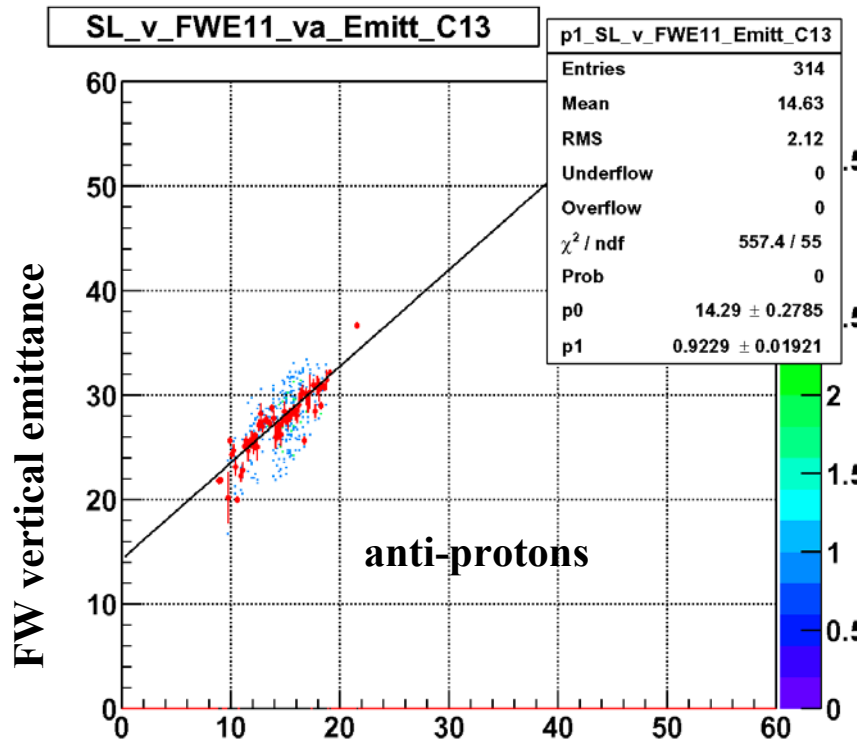


# Compare E11 to E17 FW Horizontal Emittances

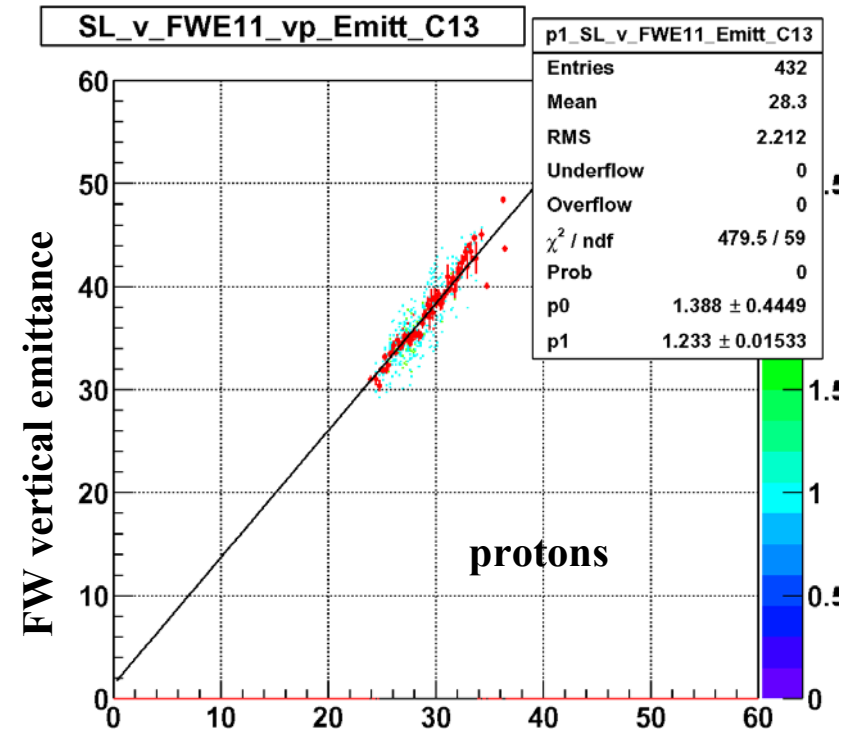
- This quantity is a fixed combination of the beta and dispersion function.
- Store 3424 lattice change is seen by horizontal Flying Wires;
- Proton detectors indicate another smaller change before store 3528 (due to RF change?) - we need to know the momentum spread to extract horizontal emittance



# Compare SyncLite to FW - Vertical



SyncLite vertical Emittance



SyncLite vertical Emittance

# Outlook: The SDA meets new challenges.

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- Mixed Source Mode operation: The Main Injector takes antiproton from both the antiproton source and the Recycler. => SuperTable has recently been expanded. Further checks needed.
- Keep doing beam physics analysis. The machines have a life of their own!.. '
- Better organization and maintenance of the software.
  - The osda/osdaphysics set of class grew without pre-conceived, "proper" OO design, originally. First phase of re-designing done, but could do better
  - Should be made easier to use..
- Enhanced reliability of the D.A. and Analysis tools
- Integrated Calibration Databases (?)
- Data Schema Evolution for basic ACNET Variable (?)

## Other Software projects...

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- Magnet Database Project (D. Box, M. Fischler)
- Tevatron Instrumentation Projects ( excluding BPM)
  - Real-time longitudinal emittance calculation for SBD ( A. Para)
  - Tevatron Tune Fitter - 1.7 GHz, 21.4 MHz (P. Lebrun)
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- Outlook : what's next ?

## BLASTMAN: From docDB (beams) 956

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Magnet properties and alignment data are used for modeling and tuning Tevatron performance.....

**For accelerator physicists who need to model and understand beam-magnet interactions, we propose to develop the Beams Lattice Alignment Survey Tracker for Modeling Accelerators Numerically (BLASTMAN) database. BLASTMAN will be a database of magnet locations, field strengths, calibrations and other magnet data that facilitate repeatable generation of lattices for modeling purposes.**

Unlike the current system where data from various sources are laboriously combined and the resulting lattices distributed via ad hoc methods, the BLASTMAN system will have documented input and output procedures with data flowing through a single source, featuring data consistency checks, and an extensible schema which will allow magnet location lattices of different geometries to be more easily and reliably constructed than is now possible.



## BLASTMAN: Status report from D. Box

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- Equipment Inventory from M.E. /TeV (D. Augustine) into -> BLASTMAN.
- New Survey data.
- Preliminary ER diagram for better integration of raw survey data
- N. Gelfand satisfied the BLASTMAN phase 1 is acceptable replacement for VAX MAGFIN db.. -> one old d.b. on the way to retirement..Need to finish maintenance tools.

# Tevatron Instrumentation Support (I)

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- Sample Bunch Display (A. Para)
  - Alvin Tollestrup came up with an algorithm to compute momentum spread and long. Emittance from pulse shape (time-wise) measurements, assuming constant phase space density along synchrotron motion.
  - and implemented it... in Mathematica..
  - Not suitable for Front-ends..
  - Rewritten in C and Lab-View, now integrated
  - We will need to re-commission this in the new SBD (better scope and front-end computer.)

## Tevatron Instrumentation (II) : Tune Fitter

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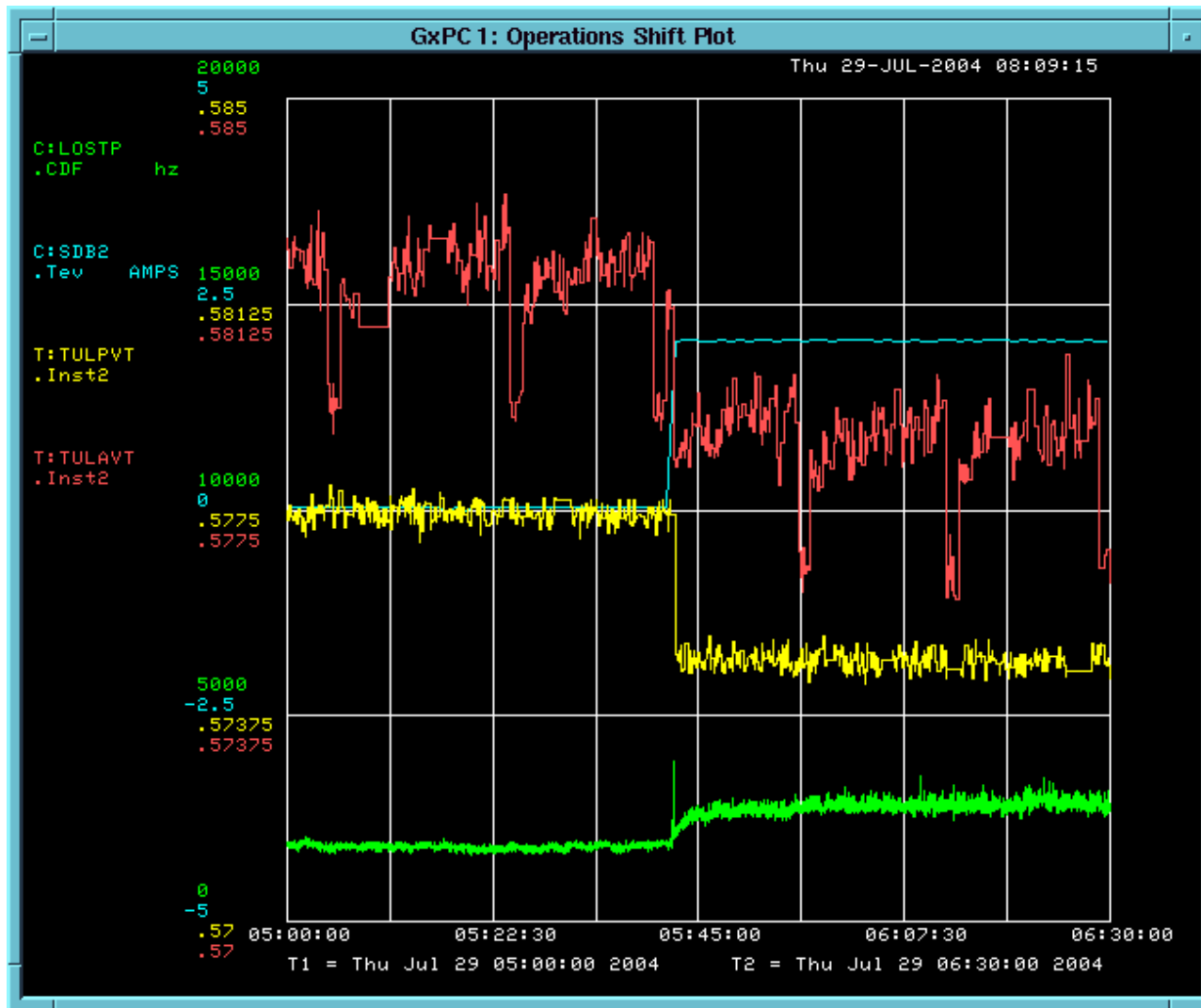
- Tune Fitters (P. Lebrun. ... *mostly.. Two years ago, i had a bit of help from J Marraffino to get started with data conversion.* )
  - Motivation: Keep track of the betatron tunes while beams are circulating...
  - Front-end consist of VSA or digitizer cards + online computers running Fast Fourier Transforms => freq spectra.
  - Must fit, "reliably" and often, such spectra, to extract "Tunes" and publish to ACNET.
  - Two of them, we have to type of Schottky devices (resonators) .. 21.4 MHz and 1.7 GZ => different tune fitters.
  - Details are <http://www-ad.fnl.gov/tevtune/>

## Tevatron Tune Fitter : example of use

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- Tuning at the beginning of the store.
- During stores.. When things go wrong..
- Studies..
  - Lattice studies ..
  - Beam-Beam studies....

# Store 3678: Flaky Sextupole Circuit...



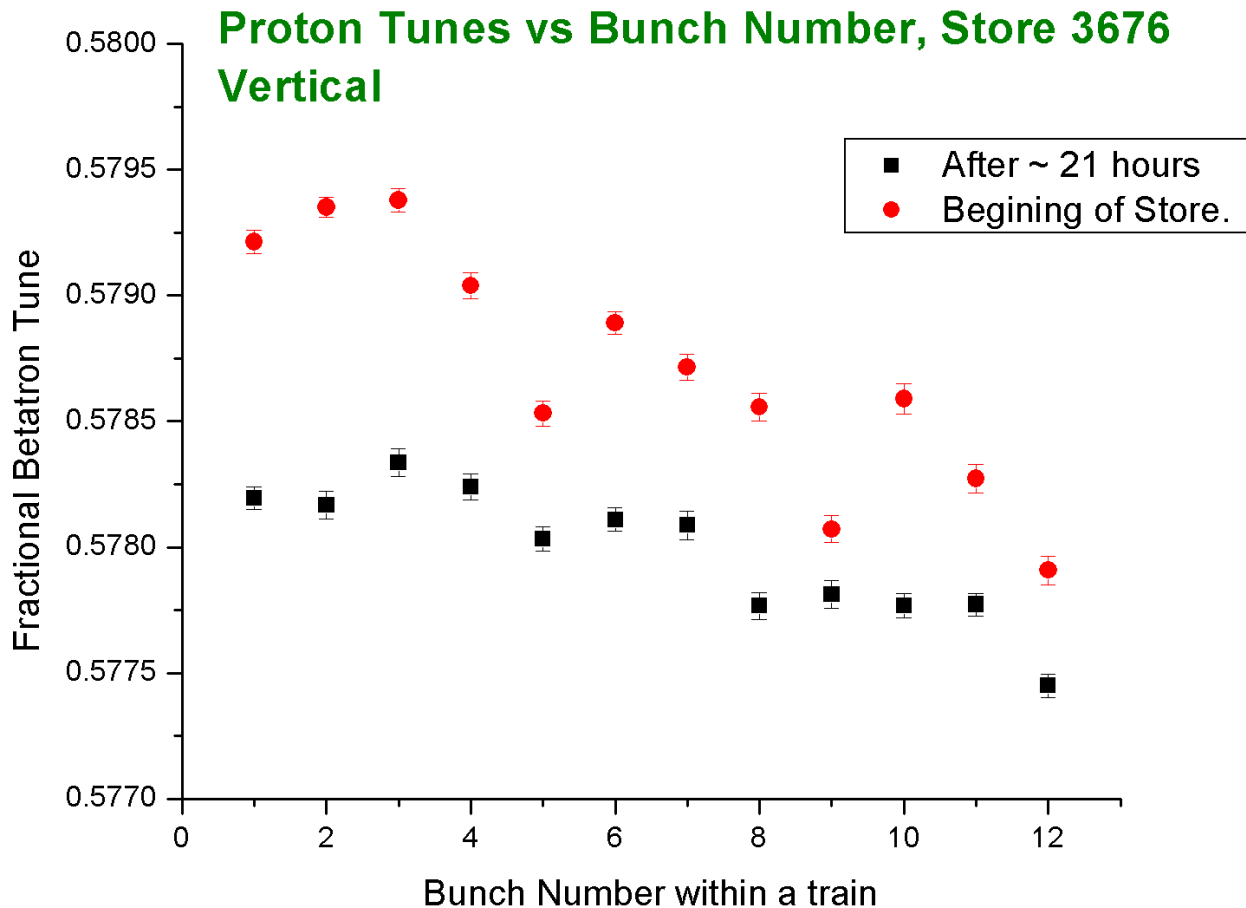
Proton tune very stable until.. ?

(Pbar tune changing because I kept changing the bunch gate every minute.. )

Proton losses responded!

Tev expert looked at circuit.. SDB2 turned on!

# Vertical Proton Tune affected by Pbars:



## Controls & VAX VMS migration

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- Three of us (Ron R., Suzanne P. and Paul L.) attend regularly the meeting of the task force on Controls & VAX VMS migration...
- Participate in the write-up on Java strategy. (Report will be out "soon")
- Move (Vax-C -> ANSI C) of the core infrastructure to Linux has started, progressing well... The plans calls for starting to migrate end-users applications beginning FY05. Existing Java applications will be maintained and upgraded. New Applications? Well.. To be decided on a case by case basis.
- Need to integrate the C/(C++ ? ) and the Java !!

A difficult project (we deal with a running machine!)  
.... with real luminosity pay-off if successful !!!

## Summary and Outlook

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- Computing Division has and can deliver software to Accelerator Division.
  - If I missed a software project, forgive me!  
Tev orbit stabilization Part of BPM....
- SDA is a working system, but it could be improved upon.
- We (AD + CD!) most definitely could do better in terms of D.A & Controls. Plenty of opportunities there.